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(54) **SYSTEM AND METHOD FOR WELD TRAINING**

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CPC ***G09B 19/24*** (2013.01); ***G09B 9/00*** (2013.01)

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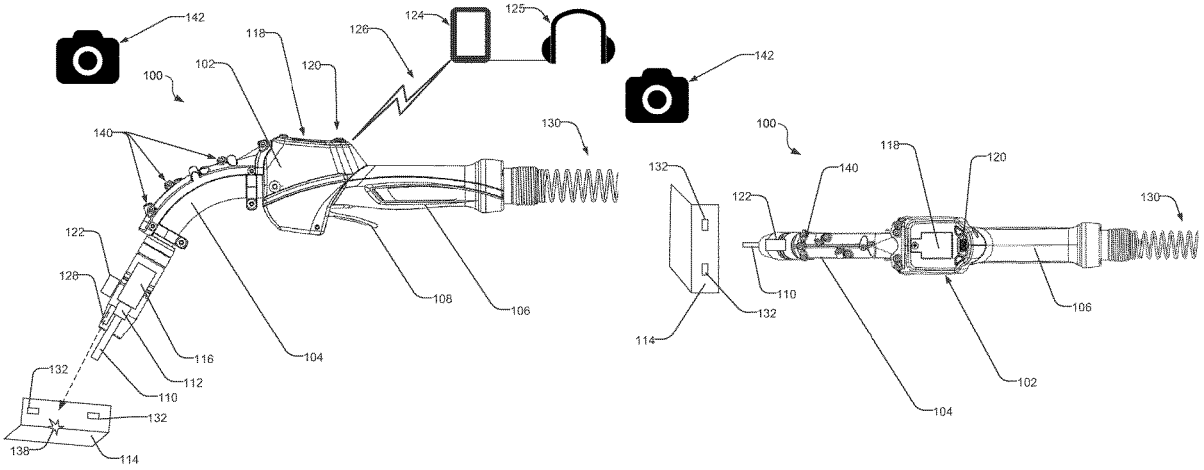
(57) **ABSTRACT**

A weld training device to provide a trainee with a real-world look and feel of a welding torch without the need to provide a welding arc. The weld training device provides adaptive vibration to simulate a welding operation. The weld training tracks performance and provides feedback to a trainee via a local display and/or via a communication to an external computing device.

20 Claims, 6 Drawing Sheets



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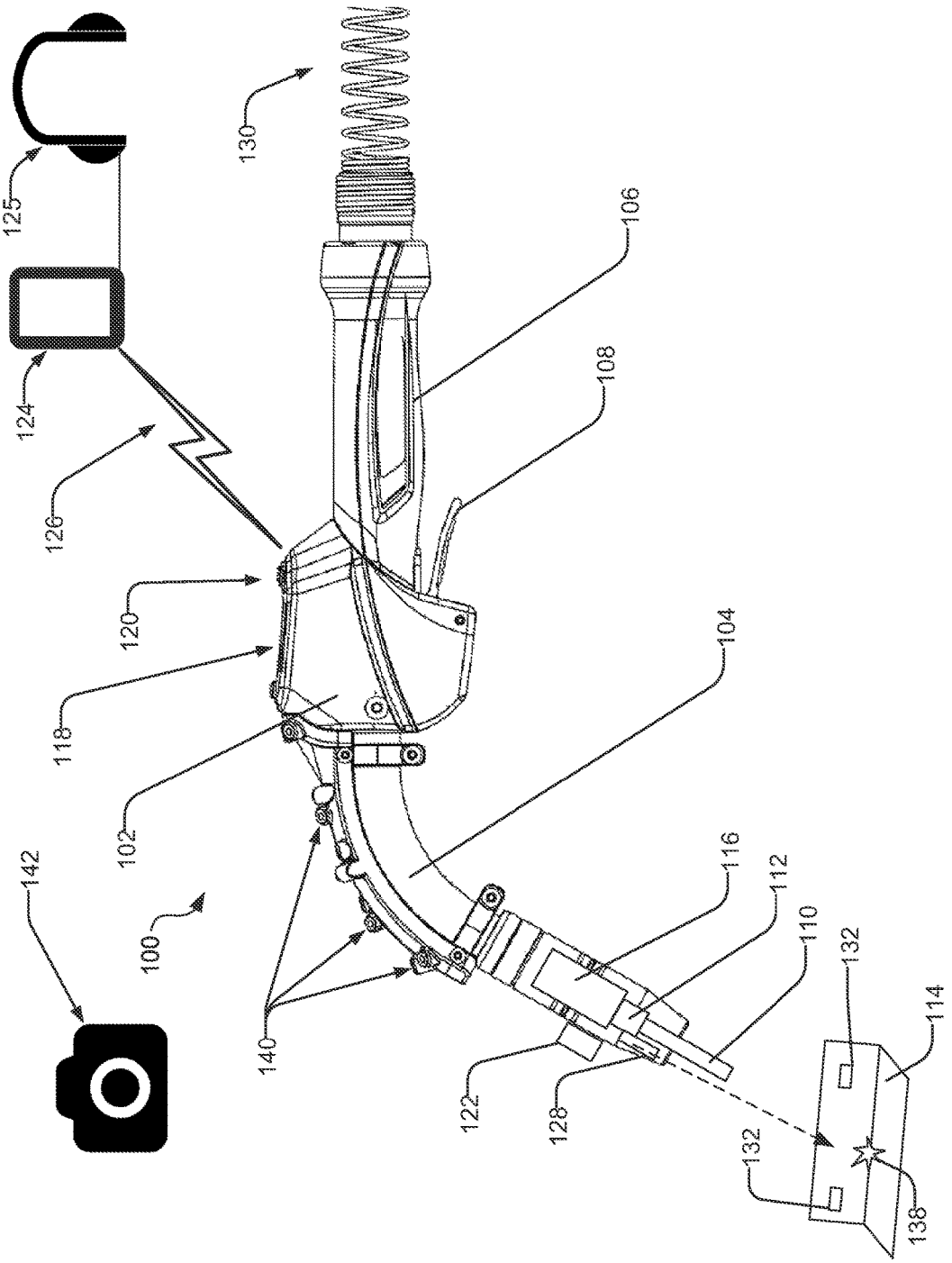
125
124
126
130
106
108
120
118
102
104
142
100
140
116
112
110
132
114
122
128
132
138

FIG. 1a

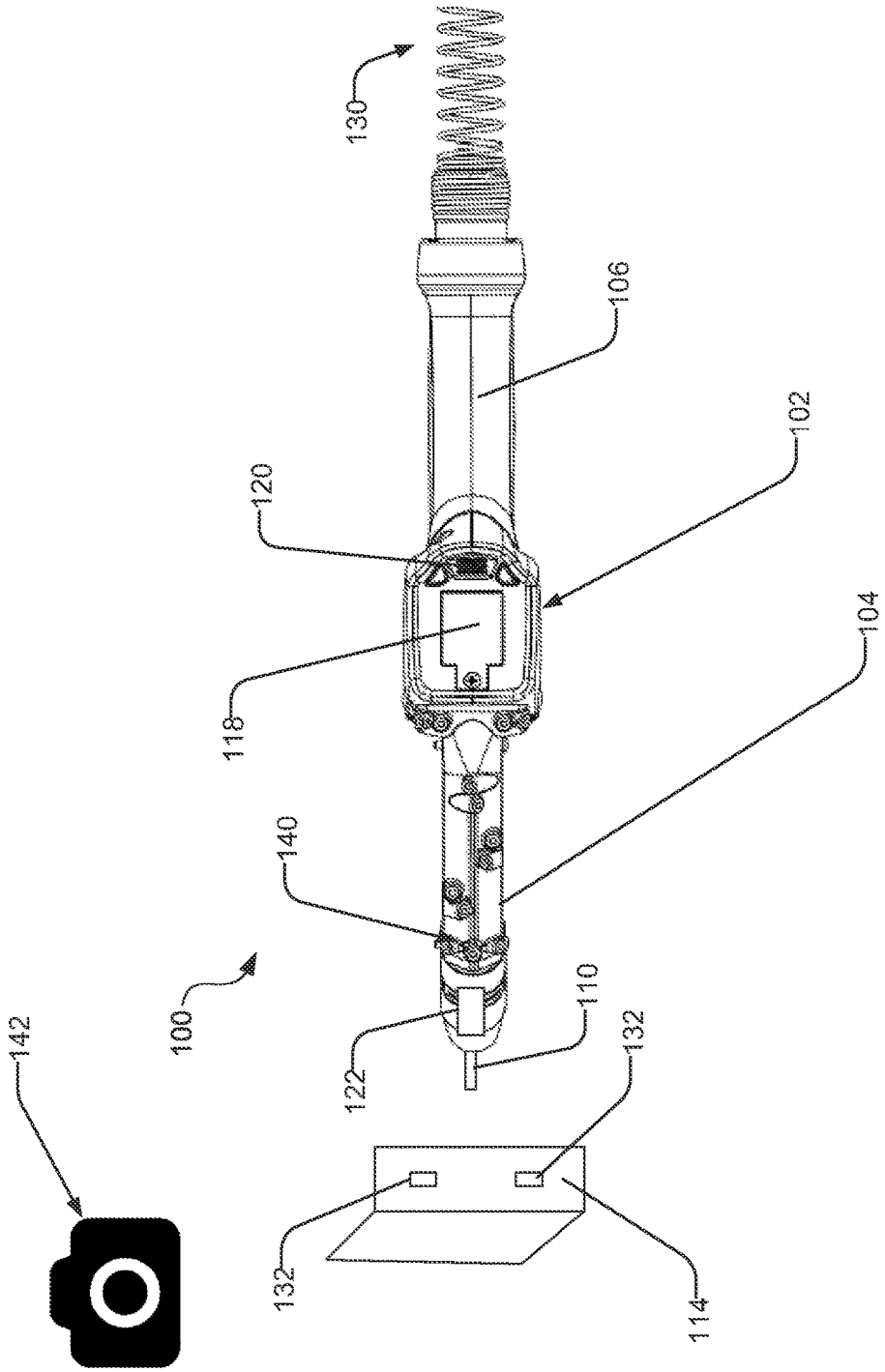

FIG. 1b

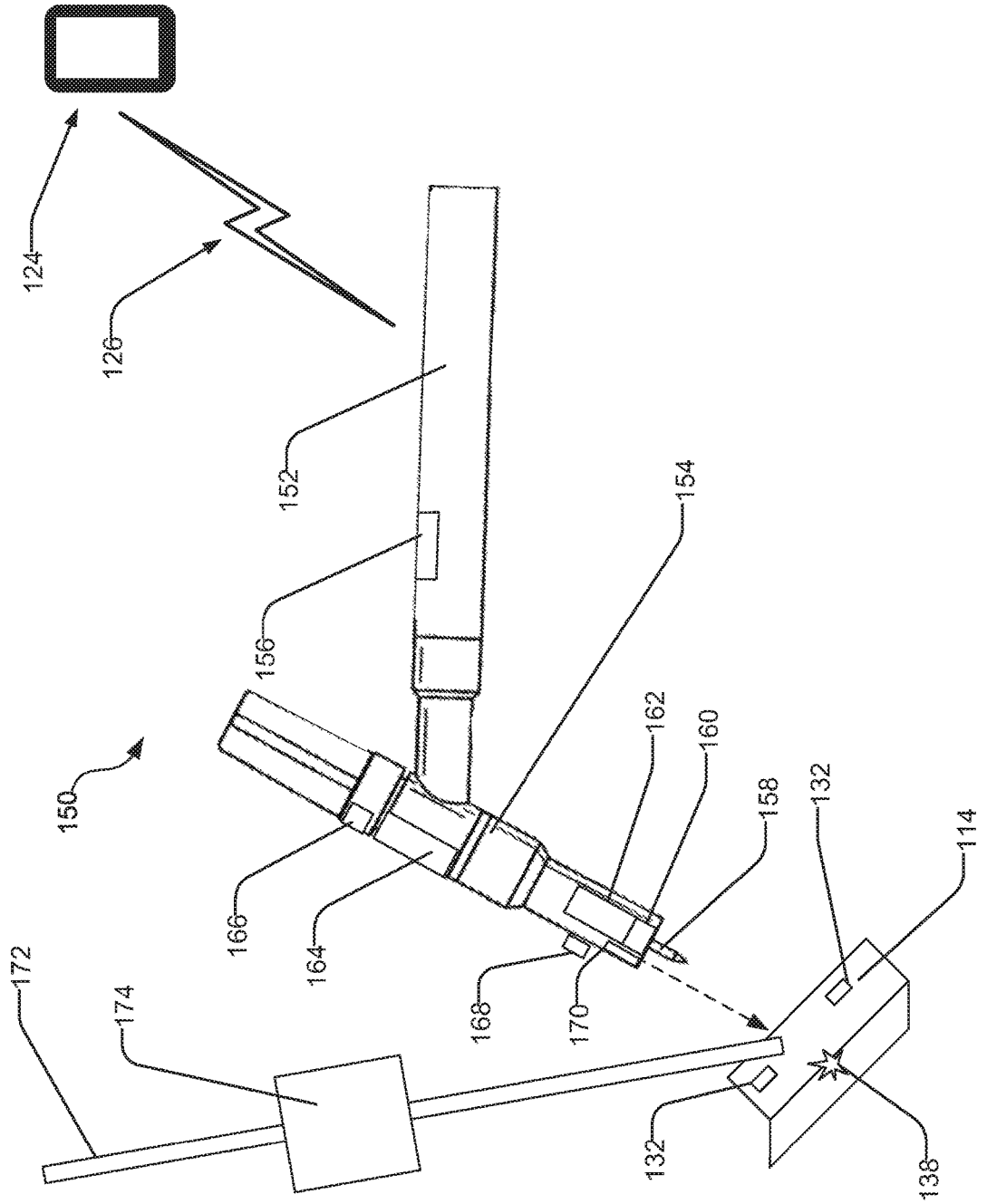
124
126
152
154
156
150
162
160
158
132
114
166
164
168
170
172
174
132
138

FIG. 1c

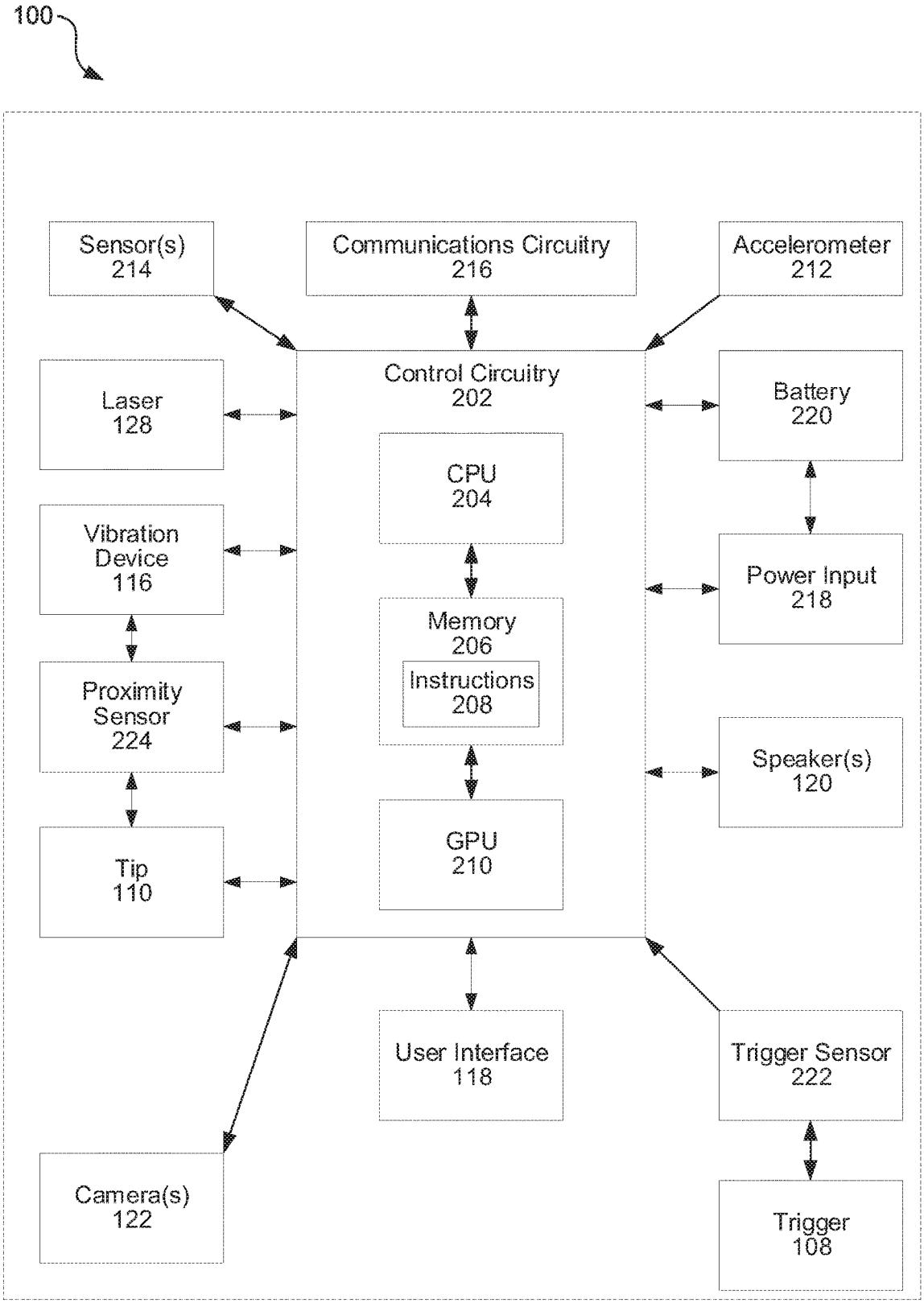
100
Sensor(s) 214
Communications Circuitry 216
Accelerometer 212
Control Circuitry 202
Laser 128
Battery 220
CPU 204
Vibration Device 116
Power Input 218
Memory 206
Instructions 208
Proximity Sensor 224
Speaker(s) 120
GPU 210
Tip 110
User Interface 118
Trigger Sensor 222
Camera(s) 122
Trigger 108

FIG. 2

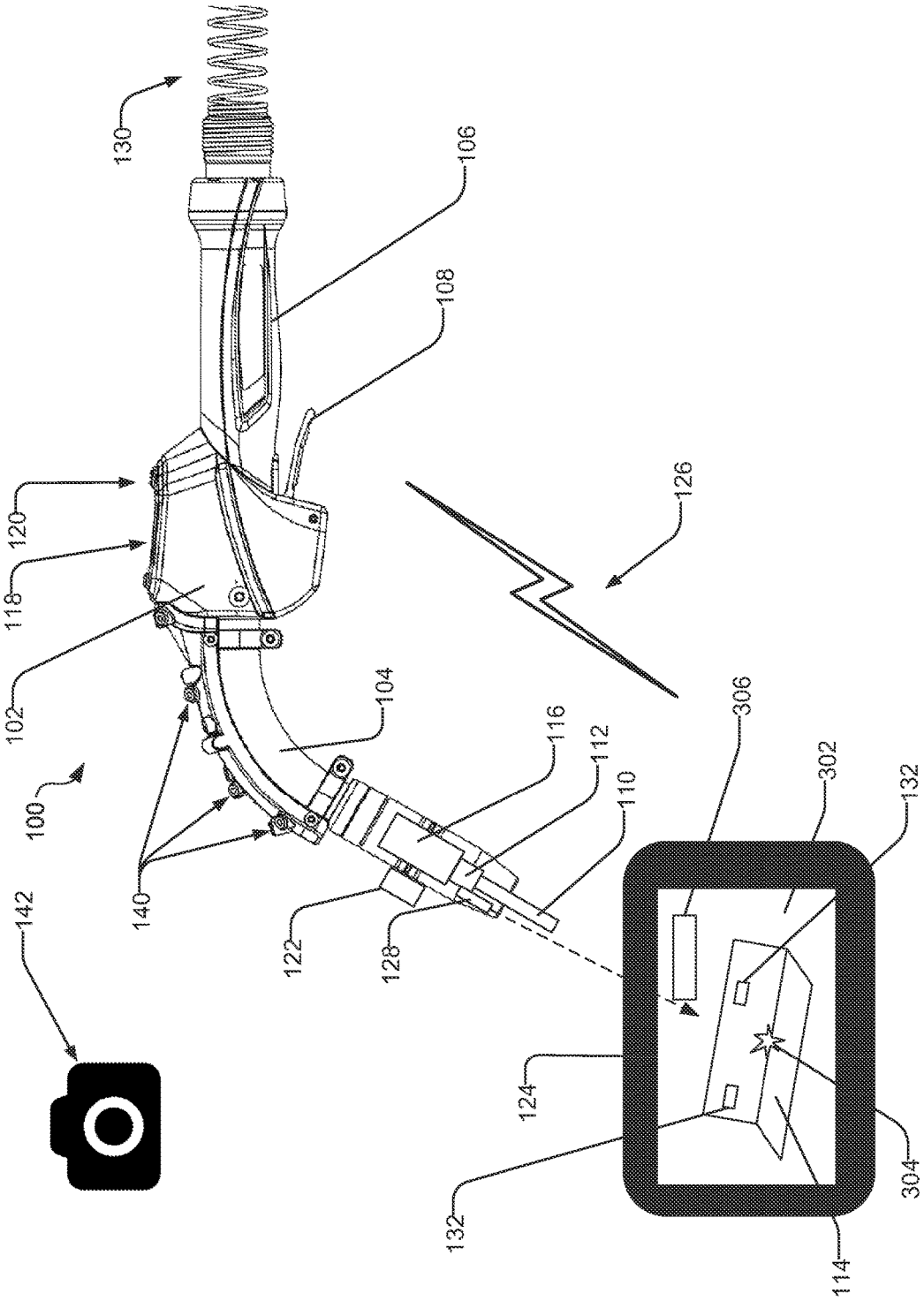
130
106
108
120
118
102
126
104
116
112
110
306
302
132
100
140
122
128
142
124
132
304
114

FIG. 3

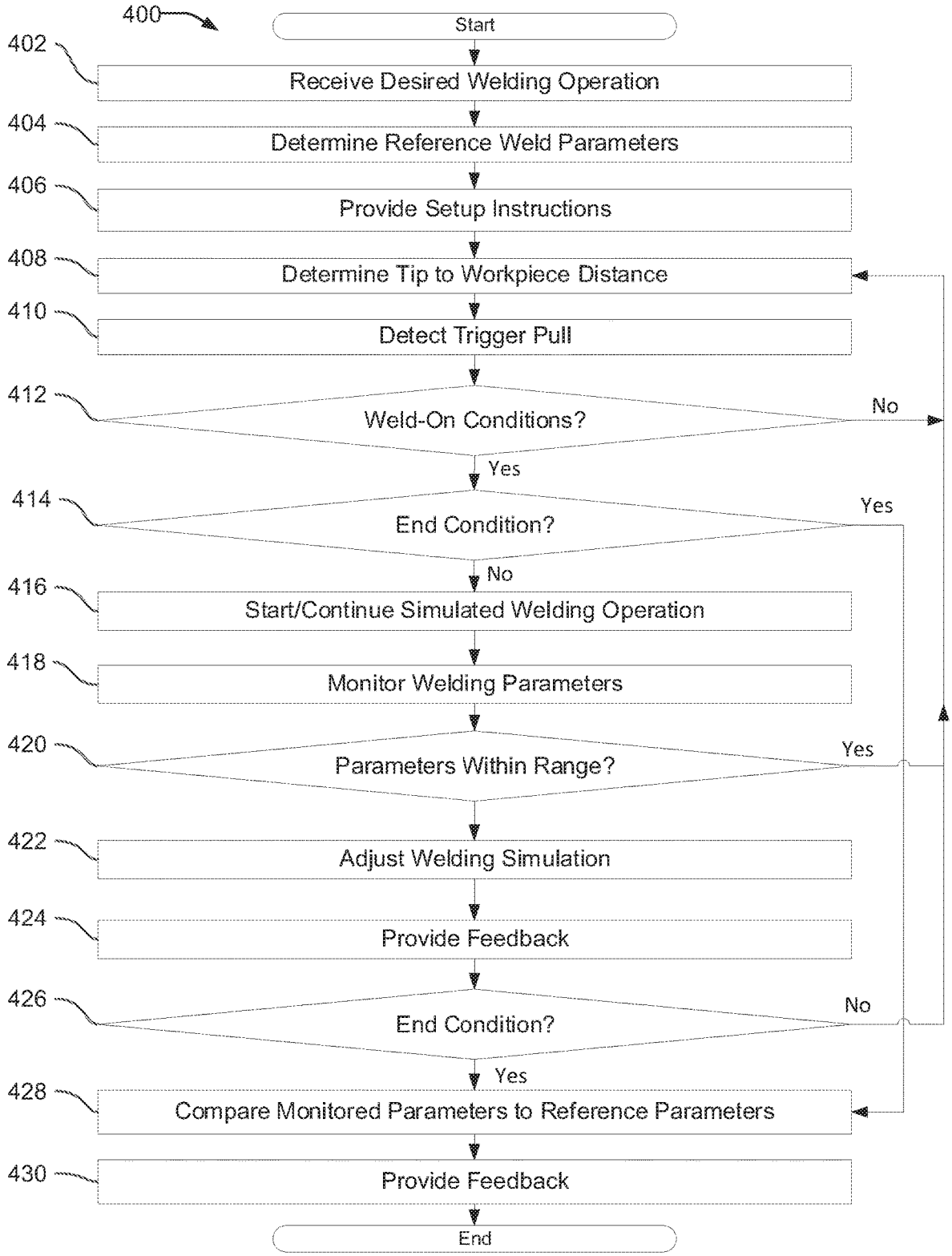
400
Start
402
Receive Desired Welding Operation
404
Determine Reference Weld Parameters
406
Provide Setup Instructions
408
Determine Tip to Workpiece Distance
410
Detect Trigger Pull
412
Weld-On Conditions?
No
Yes
414
End Condition?
Yes
No
416
Start/Continue Simulated Welding Operation
418
Monitor Welding Parameters
420
Parameters Within Range?
Yes
422
Adjust Welding Simulation
424
Provide Feedback
426
End Condition?
No
Yes
428
Compare Monitored Parameters to Reference Parameters
430
Provide Feedback
End

FIG. 4

SYSTEM AND METHOD FOR WELD TRAINING

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of U.S. Provisional Patent Application Ser. No. 62/714,501 filed Aug. 3, 2018, entitled "SYSTEM AND METHOD FOR WELD TRAINING." The entire contents of U.S. Provisional Patent Application Ser. No. 62/714,501 are expressly incorporated herein by reference.

BACKGROUND

The present disclosure relates generally to welding and, more particularly, to a weld training apparatus, system, and method.

Welding is a process that has increasingly become ubiquitous in all industries. While such processes may be automated in certain contexts, a large number of applications continue to exist for manual welding operations, the success of which relies heavily on the proper use of a welding gun or torch by a welding operator. For instance, improper torch angles (work and travel angles), contact tip-to-work distance, travel speed, and aim are parameters that may dictate the quality of a weld. Even experienced welding operators, however, often have difficulty monitoring and maintaining these important parameters throughout welding processes.

SUMMARY

Methods and systems are provided for weld training including a low cost weld training device that simulates the look and feel of a real weld torch, substantially as illustrated by and described in connection with at least one of the figures, as set forth more completely in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1***a* illustrates a perspective view of an example weld training torch and system.

FIG. **1***b* illustrates a top down view of an example weld training torch and system.

FIG. **1***c* illustrates a perspective view of an example weld training torch and system adapted to simulate a TIG welding process.

FIG. **2** shows a block diagram of an example weld training torch.

FIG. **3** illustrates a perspective view of an example weld training torch and system.

FIG. **4** shows a flowchart of an example method of simulating a welding operation using the disclosed weld training torch.

The figures are not necessarily to scale. Where appropriate, similar or identical reference numbers are used to refer to similar or identical components.

DETAILED DESCRIPTION

Conventional weld training systems may use virtual reality, augmented reality, or other training methods. As may be appreciated, these training systems may be expensive to acquire and operate. Accordingly, welding training institutions may only acquire a limited number of such training systems. Therefore, welding operators being trained by the welding training institutions may have a limited amount of time for hands-on training using the training systems.

Disclosed example methods and apparatus provide cost-effective weld training devices and/or systems for hands-on weld training. Disclosed example weld training torches provides a look and feel of a real-world welding torch. Disclosed weld training torches simulate the tactile feel of arc-on welding torches, without an actual welding arc, via a vibration device included in the weld training torch. Additionally or alternatively, disclosed weld training torches provide audio feedback and/or simulated welding arc sounds via a speaker included in the weld training torch. The weld training torch may also communicate with an external computing device, such as a smartphone, to provide feedback to the trainee as well as allow a trainee to program and interact with the weld training torch.

Disclosed example weld training torches for performing a simulated welding operation include: a torch body including a handle and a neck; at least one of a trigger and a proximity sensor coupled to the handle; a proximity sensor configured to detect a proximity between the tip and a workpiece; a tip extending from a distal end of the neck of the torch body to simulate a welding wire, the tip coupled to the torch body; and a vibration module within the torch body and mechanically coupled to the tip, the vibration module configured to vibrate in response to the detection of at least one of the trigger actuation or a proximity between the tip and the workpiece during the simulated welding operation.

Some disclosed example weld training torches further include: a communications device to communicate with an external computing device; and control circuitry configured to: receive a command via the communications device indicating a welding operation to be simulated with the weld training torch; select a vibration pattern based on the indicated welding operation; and control the vibration module to output the vibration pattern.

Some disclosed example weld training torches further include: a user interface; and control circuitry configured to: receive a command via the user interface indicating a welding operation to be simulated with the weld training torch; select a vibration pattern based on the indicated welding operation; and control the vibration module to output the vibration pattern.

In some example weld training torches, the control circuitry is configured to: monitor at least one of a pressure applied to the tip via a pressure sensor, a travel speed of the tip via a travel speed sensor, or an orientation of the torch body via an accelerometer, during a simulated welding operation; adjust the vibration pattern in response to at least one of the monitored pressure applied to the tip, the travel speed of the tip, or the orientation of the torch body.

Some disclosed example weld training torches further include a camera configured to record the simulated welding operation.

Some disclosed example weld training torches further include a camera configured to record the simulated welding operation; and a communications device configured to transmit the recorded simulated welding operation to an external computing device.

Some disclosed example weld training torches further include a speaker configured to provide simulated arc sounds during the simulated welding operation.

Some disclosed example weld training torches further include control circuitry configured to receive a command indicating a welding operation to be simulated with the weld training torch, and the simulated arc sounds are selected based on the indicated welding operation.

In some example weld training torches, the control circuitry is configured to: receive a command indicating a welding operation to be simulated with the weld training torch; and provide, via the speaker, audio instructions to complete the indicated welding operation.

In some example weld training torches, the control circuitry is configured to provide the audio instructions in real-time during the simulated welding operation.

Some disclosed example weld training torches further include: a display; and control circuitry configured to: receive a command indicating a welding operation to be simulated with the weld training torch; and provide instructions to complete the indicated welding operation, via the display.

Some disclosed example weld training torches further include: a pressure sensor configured to measure a pressure applied to the tip; and control circuitry coupled to the pressure sensor and configured to adjust an output of the vibration module based on the pressure measured by the pressure sensor.

Some disclosed example weld training torches further include: a travel speed sensor to monitor the travel speed of the tip; and control circuitry coupled to the travel speed sensor and configured to adjust an output of the vibration module based on the travel speed of the tip determined by the travel speed sensor.

Some disclosed example weld training torches further include: a position sensor to track the orientation of the torch body; and control circuitry coupled to the position sensor and configured to adjust an output of the vibration module based on the orientation of the torch body determined by the position sensor.

Some disclosed example weld training torches further include: control circuitry configured to monitor and store data representative of at least one of a pressure applied to the tip, a travel speed of the tip, or an orientation of the torch body during a simulated welding operation.

Some disclosed example weld training torches further include: a communications device configured to communicate with an external computing device, and the control circuitry is configured to transmit the data stored during a simulated welding operation to the external computing device.

In some disclosed example weld training torches, the control circuitry is configured to: compare the data stored during the simulated welding operation to predetermined target data associated with the simulated welding operation; and provide feedback, via one of a display coupled to the torch body or a speaker coupled to the torch body, to an operator based on the compared data.

Some disclosed example weld training torches further include: a laser pointer configured to provide a position guide on the workpiece.

In some disclosed example weld training torches, the length of the tip is adjustable.

Some disclosed example weld training torches further include a battery to power the weld training torch.

FIG. **1***a* illustrates a perspective view of an example weld training torch **100**. While the example weld training torch **100** of FIG. **1** is specifically presented as a gas metal arc welding (GMAW) type welding torch, a weld training torch **100** as described in this disclosure may be used to simulate various welding-type processes (e.g., flux-cored arc welding, flux-cored arc welding-gas shielded, gas tungsten arc welding (including tungsten inter gas welding), shielded metal arc welding, plasma cutting, etc.). The weld training torch **100** has a torch body **102**, a torch neck **104**, and a handle **106**. The example torch body **102**, torch neck **104**, and handle **106** are made of plastic for ease and economy of manufacturing, but may be constructed using molded plastic or rubber, metal, and/or other materials typical of actual welding torches. The plastic torch body **102**, the torch neck **104**, the handle **106** and/or, more generally, the weld training torch **100**, may be weighted to mimic the weight and feel of a real welding torch, such as a metal inter gas ("MIG") gun. The weld training torch **100** has a trigger **108**, which starts and stops a welding simulation based on depressing or releasing the trigger **108**. The weld training torch **100** also has a mock stick out wire (tip) **110** extending from the neck **104**. The tip **110** may be removable from the weld training torch **100**, such that the tip **110** may be replaced. The weld training torch may accommodate various types of tips **110** to simulate different types of welding wire. For example, the diameter of the tips **110** may be changed to represent wires having different diameters. The length of the tip **110** may also be adjustable to simulate multiple types of welding processes and welding wires.

The tip **110** connects to the weld training torch via a tip interface **112**. The tip interface **112** may include a proximity sensor, such as a pressure transducer. The proximity sensor allows control circuitry of the weld training torch to determine whether the tip is within a threshold proximity of a workpiece **114**. The weld training torch **100** also has a vibration device **116** which vibrates to simulate the tactile feel of an arc-on welding torch. The vibration device may include a vibrational motor, a piezo-electric device, weighted rotating cam, an air bladder, magnets, electromagnets, and/or any other actuator or apparatus capable of being controlled to provide vibration.

The workpiece **114** may be one or more pieces of metal, a sheet of paper, a flat surface such as a table, a tablet computer screen, etc. In examples where the workpiece **114** is a tablet computer screen, the screen may simulate the formation of a weld pool during the simulated welding operation.

FIG. **1***b* illustrated a top view of the example weld training torch **100**. As illustrated in FIG. **1***b*, the weld training torch **100** includes a user interface **118**, such as a touchscreen display. The weld training torch **100** also includes speakers **120**, which can provide audio training feedback and/or simulated arc sounds. The user interface **118** can be used to program the weld training torch **100**. For example, the user interface **118** may be used to select a welding operations and/or parameters, and/or workpiece characteristics, to simulate. The user interface **118** also gives visual feedback to the operator. The visual feedback may be user readable text, photographs, video, simulated graphics, a visual indication of torch orientation, or a combination thereof.

The parameters selected by the user may be used by the weld training torch **100** to affect the vibration, audio feedback, visual feedback, and/or other aspects of the weld training operations. For example, if the user selects voltage or wire feed speed parameters that are outside of recommended values, the vibration device **116**, the speakers **120**, and/or the workpiece **114** or other display device may provide vibration feedback, audio feedback, and/or visual feedback to mimic erratic and/or irregular arc behavior that would occur while welding using the selected parameters. In other examples, if the user selects an incorrect welding gas type or flow rate for the welding process, workpiece type, and/or wire type, the vibration device **116**, the speakers **118**, and/or the workpiece **114** or other display device may provide vibration feedback, audio feedback, and/or visual

feedback to mimic the effects of sub-optimal gas flow. Conversely, when appropriate (e.g., "ideal" or optimal) parameters are selected (by the user or automatically), and the user achieves the appropriate travel speed, work angle, and travel angle, the vibration device **116**, the speakers **118**, and/or the workpiece **114** or other display device may provide vibration feedback, audio feedback, and/or visual feedback to mimic a quality weld (e.g., the "crackling bacon noise"

The camera(s) **122** can be used to capture photographs or video of a simulated welding operation. The photographs or video can then be displayed to the user via the user interface **118** or an external computing device **124**, such as a smartphone. The weld training torch may communicate with a smartphone **124** via a communications link **126**. The communication link **126** may use any suitable protocols such as Bluetooth, Bluetooth Low Energy, WiFi, Z-Wave, Zigbee, UDP, TFTP, lwIP, HTTP, RFID and/or the like. The communications link **126** may also be a wired connection. The smartphone **124** may be used to provide feedback to the trainee as well as allow a trainee to program and interact with the weld training torch. In some examples, an external speaker, such as a speaker of the smartphone **124**, provides the audio feedback or simulated arc sounds during the simulated welding operation. In some examples, the trainee may receive audio feedback or simulated arc sounds from headphones **125**. The headphones **125** may be connected to the smartphone **124** or a headphone jack (not shown) in the weld training torch **100**. The headphones **125** may also be wirelessly connected to the smartphone **124** and/or the weld training torch **100**.

The weld training torch **100** may also include a laser **128** or other focused light device such as a focused LED. The laser **128** may act as a guide for the trainee, indicating to the trainee where the simulated weld pool would form on the workpiece **114** based on the current position and orientation of the weld training torch **100**. As will be explained in more detail below, the weld training torch may include one or more sensors, such as an accelerometer or cameras **122**, that control circuitry of the weld training torch may use to determine a position, and orientation (angle and pitch) of the weld training torch.

The weld training torch **100** may include one or more optical sensors **140**. The optical sensors **140** may also be used in conjunction with an external camera **140** to determine a travel speed, and orientation of the weld training torch **100**, and the tip **110** to workpiece **114** distance. Commonly owned U.S. Pat. No. 9,522,437 to Pfeifer et. al and U.S. Pat. No. 9,101,994 to Albrecht, describe a travel speed sensing systems using optical sensors. The entireties of U.S. Pat. Nos. 9,522,437 and 9,101,994 are incorporated herein by reference.

In some examples, the weld training torch **100** is powered by a cord **130** that plugs into an external power source, such as AC grid power. In some examples, the weld training torch **100** is battery powered, which allows the weld training torch **100** to be cordless and completely mobile.

FIG. **1***c* illustrates another example weld training torch **150** that can be used to simulate a TIG welding process. The weld training torch **150** includes a torch body **152** and a torch neck **154**. The example torch body **152** and torch neck **154** are made of plastic for ease and economy of manufacturing, but may be constructed using molded plastic or rubber, metal, and/or other materials typical of actual welding torches. The plastic torch body **152**, the torch neck **154**, and/or, more generally, the weld training torch **150**, may be weighted to mimic the weight and feel of a real TIG welding torch. The weld training torch **150** has a switch **156**, which starts and stops a welding simulation based on manipulating the switch **156**. The weld training torch **150** also has a mock tungsten electrode **158** extending from the neck **154**. The mock tungsten electrode **158** may be removable from the weld training torch **100**, such that the mock tungsten electrode **158** may be replaced. The weld training torch also has a proximity sensor **160** a vibration device **162**, a user interface **164**, a speaker **166**, one or more cameras **168**, and a laser **170**, as described with relation to the weld training torch **100** of FIG. **1***a*.

As illustrated in FIG. **1***c*, to simulate a TIG welding process, a trainee may hold a simulated welding filler rod **172**. The camera(s) **168** may sense the presence of the welding filler **172**. As will be explained in more, the simulated welding operation is adaptive based on sensed parameters, including the position of the welding filler **172**. A retraction device **174** may retract the welding filler during the simulated welding operation to simulate the deposition of the welding filler **172** onto a workpiece **114** during the simulated welding operation.

FIG. **2** is a block diagram of the weld training torch **100** of FIGS. **1***a* and **1***b*. The weld training torch **100** includes control circuitry **202**. In some examples, control circuitry **202** includes a central processing unit ("CPU") **204**, memory **206**, instructions **208** stored in memory **206**, and a graphics processing unit ("GPU") **210**. The weld training torch also includes an accelerometer **212** and/or other position sensors **214** coupled to the control circuitry. The camera (s) **122** are also coupled to the control circuitry, and may be controlled specifically by the GPU **210**. The accelerometer **212**, the camera(s) **122**, and/or the other position sensors **214** may be used by the control circuitry **202** to determine the position and orientation of the weld training torch **100**.

The weld training torch **100** also includes communications circuitry **216** coupled to the control circuitry **202**. The communications circuitry **216** allows for communication with an external computing device, such as a smartphone via communications link **126**. The communications circuitry **216** may allow communication via any suitable protocol, such as Bluetooth, Bluetooth Low Energy, WiFi, Z-Wave, Zigbee, UDP, TFTP, lwIP, HTTP, RFID and/or the like.

The weld training torch **100** also includes a power input for receiving power **218** from an external power source. In some examples, the weld training torch **100** includes a battery **220**, which allows the weld training torch **100** to be cordless and completely mobile.

The weld training torch also includes a trigger sensor **222** coupled to the control circuitry **202**, which detects when the trigger **108** is activated or released. The laser **128**, the tip **110**, the vibration device **116**, and a proximity sensor **224** are also coupled to the control circuitry **202**. The proximity sensor **224** detects when the tip **110** is within a threshold distance of a workpiece **114**. In some examples, the proximity sensor **224** is a pressure transducer, which measures a pressure applied to the tip **110** when the tip is touching the workpiece **114**. In some examples, the proximity sensor **224** is an optical sensor, which detects proximity between the tip **110** and the workpiece **114**. In some examples, the workpiece **114** may generate a magnetic field, and the proximity sensor is a Hall Effect sensor. In some examples, proximity to the workpiece **114** is determined via image processing via video captured by the camera(s) **122**. The user interface **118** is also coupled to the control circuitry **202**.

While example implementations of the weld training torch are described with reference to FIG. **2**, other implementations may be used. For example, the GPU **210**, the

CPU **204**, the communications circuitry **216**, and the memory **206** may be implemented using hardware, software, firmware, and/or any combination of hardware, software, and/or firmware. For example, components may be added, removed, replaced, combined, divided, and/or otherwise modified from the illustrated example. The CPU **204**, the GPU **210**, the speaker **120**, accelerometer **224**, the display driver **208**, the sensors **214**, the trigger sensor **222**, the memory **206**, and the communications circuitry **216** may be implemented using one or more integrated circuits and/or discrete circuits, such as general purpose processors, special purpose processors (e.g., digital signal processors), programmable logic devices, application specific integrated circuits (ASICs), systems-on-chip (SoCs), and/or any other type and/or combination of types of integrated and/or discrete circuits. Furthermore, implementations may include combinations of components and/or functions into single integrated circuit packages and/or divisions of components and/or functions into multiple integrated circuit packages.

The weld training torch **100** simulates the real world look, sound, and feel of arc welding operations without a live arc. The vibration device **116** simulates the actual vibrations a welding operator feels when operating an arc-on welding torch. The vibration device may include a vibrational motor, a piezo-electric device, weighted rotating cam, an air bladder, magnets, or electromagnets. The vibration device **116** vibrates the weld training torch **100** at a frequency simulating actual vibrations during a welding operation. For example, the vibration device may vibrate at 60 Hz to simulate GMAW welding, 60 to 200 Hz to simulate AC TIG welding, or several hundred Hz to simulate TIG or MIG pulse welding. Depending on a selected welding operation, the vibration device may be controlled to output a vibration pattern to simulate the actual vibrations caused by arc welding.

The speaker **120** also simulates real world arc sounds during a welding operation. Simulated sounds may be selected based on the selected welding operation. The laser **128** provides a position guide for the trainee, and also may simulate a weld pool that forms during the welding operation.

The control circuitry **202** uses the accelerometer **212**, the other sensors **214** (including motion sensors), and/or the camera(s) **122** to determine the position and orientation of the weld training torch **100** relative to a workpiece **114**. For example, during operation, the control circuitry **202** may be configured to use the accelerometer **212** to detect a motion (e.g., acceleration, etc.) associated with the weld training torch **100**. The control circuitry **202** may use the detected acceleration to perform various events. For example, the control circuitry **202** may cause the vibration device **116** to update the output vibration pattern in response to determining that the weld training torch **100** has rotated or translated. In some examples, the control circuitry **202** may cause the speaker **120** to update the simulated arc sounds based on the detected movement. In some examples, the control circuitry **202** may cause the speaker to provide real-time feedback to the trainee based on the sensed movement. For example, if the travel speed is too high or too low for the selected weld process, the speaker **120** may provide audio feedback to the trainee indicating that the weld travel speed is too high or too low. In some examples, the control circuitry **202** may cause the vibration device **116** to provide haptic feedback based on the sensed movement. For example, if the travel speed is too high or too low for the selected weld process, the vibration device may provide vibrate at a different known pattern or rate to indicate to the trainee that the weld travel speed is too high or too low. For example, the vibration device may indicate the travel speed is too high by increasing the vibration frequency, and may indicate that the travel speed is too low by decreasing the vibration frequency.

In some examples, the control circuitry **202** may also use the camera(s) **122** to determine the position of the welding torch **100** relative to the workpiece **114**. The workpiece may have markings (**132** in FIG. **1**) which the control circuitry **202** may use to determine the position and orientation of the weld training device relative to the workpiece.

The control circuitry **202** also uses the proximity sensor **224** to determine the proximity of the tip **110** to the workpiece **114**. The control circuitry **202** may use the detected proximity of the tip **110** to the workpiece **114** to perform various events. For example, the control circuitry **202** may cause the vibration device **116** to update the output vibration pattern in response to determining that the weld training torch has moved closer to the workpiece **114** or further from the workpiece **114**. In some examples, the control circuitry **202** may cause the speaker **120** to update the simulated arc sounds based on the detected movement. In some examples, the control circuitry **202** may cause the speaker to provide real-time feedback to the trainee based on the sensed tip **110** to workpiece **114** proximity. For example, if the tip **110** proximity to the workpiece **114** for the selected weld process is too close or too far, the speaker **120** may provide audio feedback to the trainee indicating that the proximity is too close or too far. In some examples, the control circuitry **202** may cause the vibration device **116** to provide haptic feedback based on the sensed movement. For example, if the travel speed is too high or too low for the selected weld process, the vibration device may provide vibrate at a different known pattern or rate to indicate to the trainee that the proximity is too close or too far. For example, the vibration device may indicate the proximity is too close by increasing the vibration frequency, and may indicate that the proximity is too low by decreasing the vibration frequency.

A trainee may select a welding operation to simulate via the user interface **118** or via an external device, such as a smartphone **124**. The baseline vibration pattern output by the vibration device **116** is selected based on the trainee selected welding operation. For example, the trainee may input into the user interface **118** a simulated welding operation (e.g., MIG welding); simulated welding wire type; simulated workpiece type; simulated voltage, etc., and the control circuitry **202** may select a baseline vibration pattern based on the user selected inputs. For example, the control circuitry **202** may select a 60 Hz baseline pattern for GMAW welding. Other weld parameters may also be determined based on the selected welding operation. For example, an ideal weld travel speed and tip **110** to workpiece **114** proximity may be selected based on the selected welding operation to simulate. The feedback provided by the speaker **120**, the user interface **118**, and/or the smartphone **124** is selected based on these determined parameters.

When the trainee pulls the trigger **108**, the simulated welding operation begins, and the control circuitry **202** begins to monitor the weld training torch **100** position and orientation relative to the workpiece **114**, and the tip **110** to workpiece **114** proximity. The speaker **120** may also begin to give the trainee real time instructions for completing the simulated welding operation. Once the control circuitry **202** determines that the tip **110** is within a close enough proximity to the workpiece **114** that a real world arc would be created between the workpiece **114** and the tip if actual welding-type power was provided to the welding torch, the control circuitry **202** begins the simulated welding opera-

tion. In some examples, the simulated welding operation begins when the proximity sensor **224** determines that the tip **110** has made contact with the workpiece **114**. In such examples, the proximity sensor **224** may be a pressure transducer. In some examples, the weld training torch **100** may be used to simulate non-contact welding processes. In such examples, the simulated welding operation begins when the proximity sensor determines that the tip **110** is within a threshold distance of the workpiece **114** to create a real-world welding arc.

During the simulated welding operation, the speaker **120** plays realistic arc sounds, and the vibration device **116** vibrates based on the selected welding pattern. The vibration pattern is then updated in real time based on the selected welding operation, the sensed position and orientation of the weld training torch **100**, and the sensed tip **110** to workpiece **114** proximity. For example, the vibration frequency may decrease from the baseline frequency if the proximity is too far, and increase from the baseline frequency if the proximity is too low. Similarly, the vibration frequency may decrease from the baseline frequency if the travel speed is too high, and increase from the baseline frequency if the travel speed is too low. If the sensed tip **110** to workpiece **114** proximity and sensed travel speed are within a threshold of the ideal determined values, then the vibration device **116** vibrates at the determined baseline frequency.

During the simulated welding operation, the control circuitry **202** tracks and stores in memory **206** the measurements of the proximity sensor **224**, the accelerometer **212**, the other sensors **214**, and video captured by the camera(s) **122**. During the simulated welding operation, the control circuitry **202** compares the tracked measurements to reference parameters for the selected simulated welding operation. The control circuitry **202** then provides real-time feedback to the user via the vibration device **116** or the speaker **120** during the simulated welding operation. After the simulated welding operation, the control circuitry **202** may compare the tracked and stored measurements to reference parameters stored in memory **206**. The weld training torch **100** may then provide feedback via the user interface **118** and/or the speaker **120** to the trainee based on the compared parameters. In some examples, the feedback may be provided to the trainee via the smartphone **124**. In some examples, the tracked measurements are sent via the communications link **126** to the smartphone **124**. The smartphone **124** compares the tracked measurements to reference parameters for the simulated welding operation stored in memory of the smartphone **124**. The smartphone **124** then provides feedback to the trainee. The feedback may also include video of the simulated welding operation captured by the camera(s) **122**.

Once the trigger **108** is pulled, the laser **128** may also turn on to act as a position guide on the workpiece for the trainee. The visual pattern **138** produced by the laser **128** may also simulate a weld pool **138** on the workpiece **114**. For example, as the weld training torch **100** hovers over a certain area on the workpiece **114**, the radius of the laser point on the workpiece **114** may increase, to simulate an expanding weld pool **138**. The color of the laser **128** may also change to provide feedback to the trainee. For example, a green laser may indicate that the travel speed is within the ideal range, while a red laser may indicate that the travel speed is too fast or too slow. In some examples, a red simulated weld pool **138** may indicate a weld pool **138** that is outside of a threshold of ideal parameters, which a green simulated weld pool **138** may indicate a weld pool **138** that is within a threshold of the ideal parameters.

FIG. **1***c* illustrates the weld training torch **100** configured to simulate a TIG welding process. As illustrated, a trainee may also hold a welding filler **134**. During the simulated welding operation, the camera(s) **122** may also be used by the control circuitry **202** to track the position of the welding filler **134** relative to the workpiece **114** and the tip **110**. In such examples, the tip **110** simulates a tungsten welding electrode. The control circuitry **202** may compare the relative positions the welding filler **134**, the tip **110**, and the workpiece **114** to reference positions for the selected welding process, and provide feedback to the trainee based on the comparison. The feedback may be provided in real time via the speaker **120**. The feedback may also be provided via the smartphone **124**.

As discussed above in relation to FIG. **1***c*, in some examples, a weld training torch **150** may simulate a TIG welding process. In such examples, the weld training torch **150** may contain the same internal components as the weld training torch **100** described in FIG. **2**. In such examples as illustrated in FIG. **1***c*, a retraction device **174** may be configured to retract the welding filler **172** to simulate consumption of the welding filler during a simulated welding operation. The retraction device **174** may include a motor and rollers that retract the welding filler **172** away from the workpiece **114**. The retraction device may also include communications circuitry which communicates with the control circuitry **202** of the weld training torch **150**. The control circuitry **202** then sends commands to the retraction device **174** to retract the welding filler **172** at a commanded rate during the simulated welding operation. For example, when the control circuitry **202** senses that the switch has been turned on, and that the proximity of the mock tungsten electrode and the welding filler **172** is within range of the workpiece **114** to begin the welding operation, the retraction device **174** begins to retract the welding filler **172** away from the workpiece. This retraction teaches a trainee how to hold a welding filler **172** during a simulated welding operation. The rate of retraction of the welding filler **172** may increase or decrease based on the mock tungsten electrode **158** to workpiece **114** proximity, the position the travel speed of the weld training torch **150**, the selected simulated welding process, and any other parameter.

Returning to FIG. **1***a*, the smartphone **124** may also be used to interact with and program the weld training torch **100**. For example, the smartphone **124** may be used to provide firmware updates to the weld training torch **100**. The smartphone **124** may also be used to select a weld process and/or welding parameters to simulate. For example, a trainee may select a simulated workpiece type, a simulated welding wire type, a simulated voltage, a simulated current, etc. The simulated vibration and audio provided by the weld training torch **100** during the simulated welding operation is selected based on the inputs selected by the trainee on the smartphone **124**. The smartphone **124** also provides instructions to the trainee. For example, the smartphone **124** may provide user readable instructions to the trainee for operating the weld training torch **100**. The smartphone **124** may also provide audio instructions to the trainee. The smartphone **124** may also provide instructional videos and simulated graphics to instruct the trainee on the use of the weld training torch **100**, as well as instructions to improve the trainee's welding technique based on the trainee's simulated welding operations.

In some examples, as illustrated in FIG. **3**, the smartphone **124** or other tablet computer may be used to simulate a workpiece **114**. The smartphone **124** screen **302** may display a workpiece **114**. The simulated workpiece **114** may have

various markings **132** to which act as position guides for the trainee. The control circuitry **202** may also use the markings **132** to determine the position and orientation of the weld training torch **100** relative to the smartphone screen **302** via processing images received from the camera(s) **122**. In some examples, the proximity sensor **224** of the weld training torch **100** detects the proximity of the weld training torch to the screen **302** via detecting light radiated from the screen. As described above, the weld training torch may adjust the vibration pattern and simulated audio based on the tip **110** to screen **302** proximity, as well as the sensed position and orientation of the weld training torch **100** relative to the screen **302**.

As described above, the weld training torch **100** may communicate with the smartphone **124** via the communications link **126**. As such, the screen may adapt the simulated workpiece **114** in response to the position and movement of the weld training torch during a simulated welding operation to simulate the deposition of welding wire. For example, the smartphone **124** may display a weld pool **304** during the simulated welding operation that is adaptive during the simulated welding operation. For example, as the tip **110** hovers over the weld pool **304**, the weld pool **304** may grow in size. Further, the weld pool may move or adapt as the tip **110** moves across the screen **302**.

The screen **302** may also provide other visual feedback to the trainee, such as text **306**. The text **306** may indicate to the trainee that the tip **110** is too close to the screen **302** or too far away from the screen **302**.

FIG. **4** is a flow chart of an exemplary method **400** of simulating a welding operation using the weld training torch **100**. The example method **400** may be partially or completely implemented by executing machine readable instructions using the control circuitry **202** (i.e., memory **206** and CPU **204**) of FIG. **2**.

At block **402**, the control circuitry **202** received a desired welding operation to simulate. For example, a trainee may select a welding operation to simulate via the user interface **118**, or via an application on a smartphone **124**. This selection of a welding operation to simulate is then received by the control circuitry **202**. At block **404**, the control circuitry **202** determines reference parameters for the selected welding operation. For example, the selected reference weld parameters may be stored in memory **206**. The reference weld parameters may include tip **110** to workpiece **114** distance, torch travel speed, torch orientation, etc. At block **404**, the control circuitry **202** selects instructions for setting up and/or running the simulated welding operation to provide to the trainee. At block **406**, the user interface **118** may display the instructions. For example, the user interface **118** may provide text instructions, a video instruction, or simulated graphics instructing the user how to set up and run the simulation. For example, the instruction may include information regarding setting up a simulated workpiece **114** information regarding an ideal tip **110** to workpiece **114** distance; or an ideal travel speed. The instructions may also include information relating to how to begin the simulation.

At block **408**, the control circuitry **202** monitors the tip **110** to workpiece **114** distance. For example, as described above, the weld training torch **100** may include a proximity sensor coupled to the control circuitry **202** which the control circuitry **202** may use to determine the tip **110** to workpiece **114** distance. In some examples, the camera(s) **122** may be used to determine the tip **110** to workpiece **114** distance. At block **410**, the control circuitry **202** monitors the trigger sensor **222** to determine whether the trigger **108** has been pulled. At block **412**, the control circuitry **202** checks if the weld-on conditions are satisfied. The weld-on conditions include the pulled trigger detected at block **410** and a tip **110** to workpiece **114** distance within a threshold proximity. The threshold proximity is the tip **110** to workpiece **114** distance required for a live welding arc to begin in a real world weld for the selected welding operation. If both weld-on conditions are satisfied, then the control circuitry proceeds to block **414**. If both weld-on conditions are not satisfied, then the control circuitry returns to block **408** to continue to monitor both weld-one conditions.

At block **414**, the control circuitry **202** determines if an end simulation condition exists. For example, the simulation may run for a certain amount of time, and if the time has run out, the end simulation condition exists. In some examples, the trainee may toggle a control on the weld training torch **100** to end the simulation. In some examples, when the trainee releases the trigger **108**, an end simulation condition exists. If an end simulation condition exists, the control circuitry **202** proceeds to block **428**. If an end simulation condition does not exists, the control circuitry **202** proceeds to block **416**.

At block **416**, the control circuitry **202** begins the simulated welding operations. The control circuitry **202** commands the vibration device **116** to vibrate at a pattern determined based on the selected welding operation. The control circuitry **202** also commands the speaker **120** to provide simulated arc sounds based on the selected welding operation. The control circuitry **202** also commands the laser **128** to provide the simulated weld pool **138**.

At block **418**, the control circuitry monitors the welding parameters of the weld training torch **100**. For example, the control circuitry **202** monitors the travel speed or torch orientation of the weld training torch **100** via camera(s) **122**, and/or accelerometer **212** as described above. The control circuitry **202** also monitors the tip **110** to workpiece **114** proximity as described in relation to block **408**. The control circuitry **202** also monitors torch angle via the accelerometer **212** and/or camera(s) **122**. The control circuitry **202** stores the monitored parameters in memory **206** for later analysis.

At block **420**, the control circuitry **202** compares the monitored parameters to reference parameters determined in block **404**. The control circuitry **202** determines if the monitored parameters are within a threshold range of the reference parameters determined at block **404**. If the monitored parameters are within a threshold range, then the control circuitry **202** proceeds back to block **408** to continue the simulated welding operation. If one or more of the parameters are not within the threshold range, the control circuitry **202** proceeds to block **422**.

At block **422**, the control circuitry **202** adjusts the welding simulation. For example, the control circuitry **202** may increase or decrease the vibration frequency provided by the vibration device **116** to adapt to the monitored weld parameters. The control circuitry **202** may also adjust the simulated weld pool **138** and the simulated arc sounds provided by the speaker **120**.

At block **424**, the control circuitry **202** provides real-time feedback to the trainee. For example, the speaker **120** may provide audio instructions to the trainee telling the trainee to adjust travel speed; tip **110** to workpiece **114** distance; or torch orientation, or torch angle in order to bring the monitored parameters closer to the reference parameters.

At block **426**, the control circuitry **202** determines if an end simulation condition exists. For example, the simulation may run for a certain amount of time, and if the time has run out, the end simulation condition exists. In some examples, the trainee may toggle a control on the weld training torch

100 to end the simulation. In some examples, when the trainee releases the trigger 108, an end simulation condition exists. If an end simulation condition exists, the control circuitry 202 proceeds to block 428. If an end simulation condition does not exists, the control circuitry 202 proceeds to block 408 to continue the simulated welding operation.

At block 428, the control circuitry 202 compares the monitored parameters stored in memory 206 during the simulated welding operation to reference parameters 404. At block 430, the control circuitry 202 provides feedback based on the compared parameters to the trainee to improve the trainee's welding ability. Such feedback may include text, simulated graphics, or a video displayed on the user interface 118 or a smartphone 124. Feedback may also include audio instructions which may be provided via the speaker 120 or a smartphone 124.

As utilized herein the terms "circuits" and "circuitry" refer to physical electronic components (i.e. hardware) and any software and/or firmware ("code") which may configure the hardware, be executed by the hardware, and or otherwise be associated with the hardware. As used herein, for example, a particular processor and memory may comprise a first "circuit" when executing a first one or more lines of code and may comprise a second "circuit" when executing a second one or more lines of code. As utilized herein, "and/or" means any one or more of the items in the list joined by "and/or". As an example, "x and/or y" means any element of the three-element set {(x), (y), (x, y)}. In other words, "x and/or y" means "one or both of x and y". As another example, "x, y, and/or z" means any element of the seven-element set {(x), (y), (z), (x, y), (x, z), (y, z), (x, y, z)}. In other words, "x, y and/or z" means "one or more of x, y and z". As utilized herein, the term "exemplary" means serving as a non-limiting example, instance, or illustration. As utilized herein, the terms "e.g.," and "for example" set off lists of one or more non-limiting examples, instances, or illustrations. As utilized herein, circuitry is "operable" to perform a function whenever the circuitry comprises the necessary hardware and code (if any is necessary) to perform the function, regardless of whether performance of the function is disabled or not enabled (e.g., by a user-configurable setting, factory trim, etc.).

Control circuitry, as used herein, includes digital and analog circuitry, discrete or integrated circuitry, microprocessors, DSPs, etc., software, hardware and firmware, located on one or more boards, that form part or all of a controller, and are used to control a welding process, or a device such as a power source or wire feeder.

Feedback, as used herein, includes a signal indicative of or responsive to an output or intermediate signal, which is provided to the controller and control decisions are made in response thereto. Feedback circuit, as used herein, includes a circuit that provides a signal indicative of or responsive to an output or intermediate signal. Feedback signal, as used herein, includes one or more signals that provide information about one or more parameters being monitored, such as output current and output voltage.

The present methods and/or systems may be realized in hardware, software, or a combination of hardware and software. The present methods and/or systems may be realized in a centralized fashion in at least one computing system, or in a distributed fashion where different elements are spread across several interconnected computing systems. Any kind of computing system or other apparatus adapted for carrying out the methods described herein is suited. A typical combination of hardware and software may be a general-purpose computing system with a program or other code that, when being loaded and executed, controls the computing system such that it carries out the methods described herein. Another typical implementation may comprise an application specific integrated circuit or chip. Some implementations may comprise a non-transitory machine-readable (e.g., computer readable) medium (e.g., FLASH drive, optical disk, magnetic storage disk, or the like) having stored thereon one or more lines of code executable by a machine, thereby causing the machine to perform processes as described herein.

As utilized herein, circuitry is "operable" to perform a function whenever the circuitry comprises the necessary hardware and code (if any is necessary) to perform the function, regardless of whether performance of the function is disabled or not enabled (e.g., by a user-configurable setting, factory trim, etc.).

While the present method and/or system has been described with reference to certain implementations, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the present method and/or system. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from its scope. Therefore, the present method and/or system are not limited to the particular implementations disclosed. Instead, the present method and/or system will include all implementations falling within the scope of the appended claims, both literally and under the doctrine of equivalents.

What is claimed is:

1. A weld training torch for performing a simulated welding operation, the weld training torch comprising:
- a torch body comprising a handle and a neck;
- a tip extending from a distal end of the neck of the torch body, the tip coupled to the torch body;
- a trigger, or a proximity sensor, coupled to the handle;
- a vibration module within the torch body and mechanically coupled to the tip, the vibration module configured to vibrate in response to an actuation of the trigger or a detection, by the proximity sensor, of a proximity between the tip and a workpiece that is less than a threshold proximity;
- a communications device to communicate with an external computing device; and
- control circuitry configured to:
  - receive a command via the communications device indicating a welding operation to be simulated with the weld training torch,
  - select a vibration pattern based on the indicated welding operation, and
  - control the vibration module to output the vibration pattern.

2. The weld training torch of claim 1, wherein the control circuitry is configured to:
- monitor at least one of a pressure applied to the tip via a pressure sensor, a travel speed of the tip via a travel speed sensor, or an orientation of the torch body via an accelerometer, during the simulated welding operation; and
- adjust the vibration pattern in response to at least one of the monitored pressure applied to the tip, the travel speed of the tip, or the orientation of the torch body.

3. The weld training torch of claim 1 further comprising:
- a camera configured to record the simulated welding operation, wherein the communications device is configured to transmit the recorded simulated welding operation to the external computing device.

4. The weld training torch of claim 1, further comprising a speaker configured to provide simulated arc sounds during the simulated welding operation.

5. The weld training torch of claim 4, wherein the control circuitry is configured to select the simulated arc sounds based on the indicated welding operation.

6. The weld training torch of claim 4, wherein the control circuitry is configured to: provide, via the speaker, audio instructions to complete the indicated welding operation.

7. The weld training torch of claim 6, wherein the control circuitry is configured to provide the audio instructions in real-time during the simulated welding operation.

8. The weld training torch of claim 1, further comprising: a display, the control circuitry being configured to: provide instructions to complete the indicated welding operation, via the display.

9. The weld training torch of claim 1, further comprising: a pressure sensor configured to measure a pressure applied to the tip, the control circuitry being coupled to the pressure sensor and configured to adjust an output of the vibration module based on the pressure measured by the pressure sensor.

10. The weld training torch of claim 1, further comprising: a travel speed sensor to monitor the travel speed of the tip, the control circuitry being coupled to the travel speed sensor and configured to adjust an output of the vibration module based on the travel speed of the tip determined by the travel speed sensor.

11. The weld training torch of claim 1, further comprising: a position sensor to track the orientation of the torch body, the control circuitry being coupled to the position sensor and configured to adjust an output of the vibration module based on the orientation of the torch body determined by the position sensor.

12. The weld training torch of claim 1, wherein the length of the tip is adjustable.

13. A weld training torch for performing a simulated welding operation, the weld training torch comprising:

a torch body comprising a handle and a neck;

a tip coupled to, and extending from, a distal end of the neck of the torch body;

a pressure sensor configured to measure a pressure applied to the tip;

a vibration module within the torch body, the vibration module configured to produce a vibration output in response to an actuation of a trigger of the weld training torch, or a detection of a proximity between the tip and a workpiece that is less than a threshold; and

control circuitry coupled to the pressure sensor, the control circuitry configured to adjust the vibration output of the vibration module based on the pressure measured by the pressure sensor.

14. The weld training torch of claim 13, further comprising a speaker configured to provide simulated arc sounds during the simulated welding operation, the control circuitry configured to select the simulated arc sounds based on a selected welding operation.

15. The weld training torch of claim 13, wherein the pressure sensor is in communication with the tip and the vibration module.

16. The weld training torch of claim 13, wherein the pressure sensor is a pressure transducer.

17. A weld training torch for performing a simulated welding operation, the weld training torch comprising:

a torch body comprising a handle and a neck;

a tip coupled to, and extending from, a distal end of the neck of the torch body;

a trigger, or a proximity sensor, coupled to the handle;

a vibration module within the torch body, the vibration module configured to vibrate in response to an actuation of the trigger of the weld training torch, or a detection, by the proximity sensor, of a proximity between the tip and a workpiece that is less than a threshold;

a user interface; and

control circuitry configured to:

receive a command via the user interface indicating a welding operation to be simulated with the weld training torch,

select a vibration pattern based on the indicated welding operation, and

control the vibration module to vibrate according to the vibration pattern.

18. The weld training torch of claim 17, further comprising a speaker configured to provide simulated arc sounds during the simulated welding operation, the control circuitry configured to select the simulated arc sounds based on a selected welding operation.

19. The weld training torch of claim 17, further comprising a pressure sensor configured to measure a pressure applied to the tip, the control circuitry configured to control the vibration module based on the pressure measured by the pressure sensor.

20. The weld training torch of claim 17, wherein the vibration module is coupled to the tip via an interface.

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